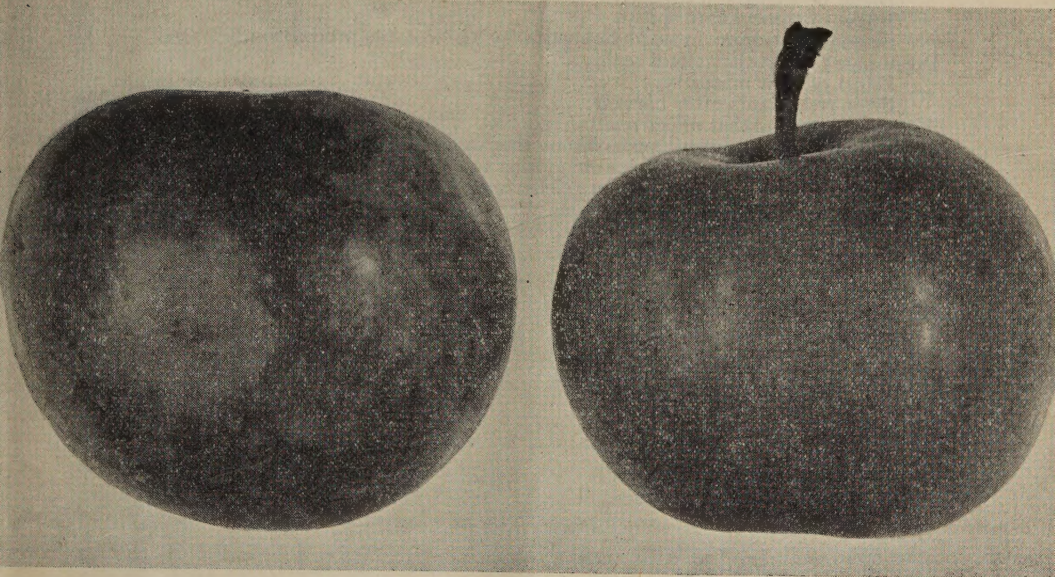
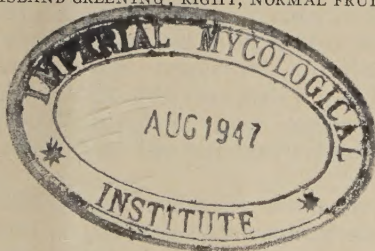


Studies on Storage Scald of Apples

R. M. Smock and F. W. Southwick



LEFT, STORAGE SCALD ON RHODE ISLAND GREENING; RIGHT, NORMAL FRUIT



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P.A.B

18 JUL 1947

STUDIES ON STORAGE SCALD OF APPLES

R. M. SMOCK AND F. W. SOUTHWICK

Apple scald, a storage disorder of the apple, constitutes a major source of economic loss to the apple growers of the world. Few varieties of apples are entirely resistant to this disease in storage, but some sorts are definitely more susceptible than others. Among those that are very susceptible are Rhode Island Greening, Northwestern Greening, and Cortland. It is often seen on other varieties such as Rome Beauty, Delicious, Grimes Golden, Stayman Winesap, Wealthy, and Baldwin. McIntosh and Northern Spy varieties are fairly resistant to the trouble, but the disease sometimes affects even these varieties.

Scald is characterized by a superficial browning of the outer layers of cells of the apple. Usually, just the epidermal cells with the few pigmented layers of cells beneath the epidermis are affected. In severe cases the cortical areas of the flesh may be injured to a depth of a quarter of an inch or more. This trouble does not impair the cooking or eating quality of pared fruits that are not seriously affected, but because of its unsightly appearance it greatly reduces the market value of the fruit. Fungi often attack the scalded portions and cause rotting, and this in turn causes heavy secondary losses.

Fruits removed from storage may have no visible scald, but after remaining at room temperature for a day or two may become seriously scalded. The disease was caused in storage, however, and in its early stages it requires high temperatures to cause the diseased portions to turn brown. If the fruit is allowed to remain in storage long enough, scald will become visible even at low temperatures. Proof of the fact that it is a storage disorder is that even very susceptible varieties held continuously at relatively high temperatures after harvest will not develop scald.

The work of Brooks, Cooley, and Fisher (1919b) demonstrated that this trouble was physiological in its origin. It seemed evident that the vapors emanating from the apples themselves were responsible for the trouble. They found that the trouble could be controlled reasonably well by wrapping the apples or by packing them with shreds of paper impregnated with mineral oil. This method of control has been the standard recommendation for 25 years.

On varieties such as McIntosh that are not ordinarily extremely susceptible to this trouble, it may be serious in controlled-atmosphere storage unless quantities of oiled paper are used. This seems to be true because the volatile materials responsible for the trouble tend to accumulate in gastight, unventilated rooms.

One of the objects of this study was to find a means of control more satisfactory than oiled paper. Another object of this study was to determine something of the nature of the volatiles responsible for scald. The work

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of the junior author was particularly concerned with this phase of the problem (Southwick, 1945a and b). In addition, the relation of seasonal fluctuation of volatile production and seasonal variations in the amount of scald were examined. The effects of certain orchard, prestorage, and storage factors as they affected the production of this trouble were studied.

METHODS

All the apples used were from the Cornell University orchards at Ithaca, New York. Unless otherwise noted all lots were made up of two-bushel samples.

The procedures followed in the controlled-atmosphere storage were those described in another publication by Smock and Van Doren (1941).

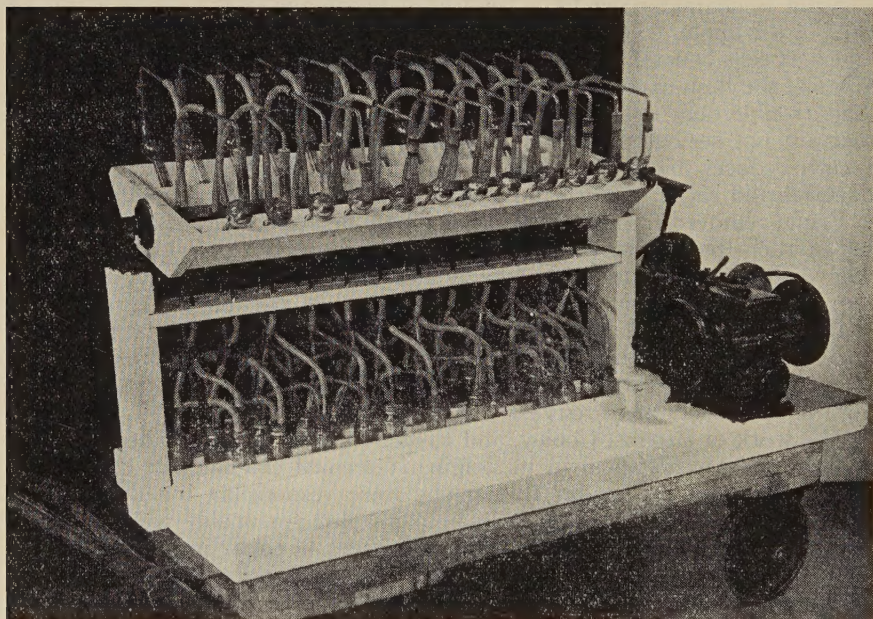


FIGURE 1. MERCURY "HEART" PUMP USED TO CIRCULATE ATMOSPHERES IN SMALL-SCALE CONTROLLED-ATMOSPHERE EXPERIMENTS

In small-scale controlled-atmosphere experiments the atmospheres were circulated in some of the experiments by means of a mercury "heart" pump. This closed-system pump is illustrated in figure 1. In the small-scale experiments in which air was used, a vacuum pump was used. Rates of air movement or displacement are described in the text. Measurement of volatile materials was done by the method of Gerhardt and Ezell (1939) with the modifications described by Southwick (1945a). Scald indicated as "slight" in the data was inconspicuous enough so that the apples could be marketed. "Severe" scald described apples that were totally unmarketable.

ORCHARD FACTORS THAT AFFECT SCALD

EFFECT OF DEFOLIATION, FRUIT-SHADING, AND LIMB-SHADING

Various tree treatments were made in the orchard to try to discover their effects on scald susceptibility in storage.

Single large limbs were used in each treatment. After the limbs were defoliated, no more leaves were removed even though some subsequently appeared. Limbs were shaded with three layers of cheesecloth. Individual fruits were shaded with white bond paper impregnated with wax emulsion to make it weatherproof. Individual fruits were shaded also with black cloth. The purpose of the latter treatment was to exclude most of the light and yet induce a higher temperature around the fruit. The white shades excluded most of the light from the fruit, but presumably did not result in higher than normal temperatures around the fruit. Limb and fruit treatments were made early in July each year. Samples taken from these limbs usually comprised one-half bushel of fruit, but sometimes less.

Rhode Island Greening, 1941-42 and 1942-43. These treatments were made on the same two Greening trees over a period of two years. The same limbs were not given the defoliation or shading treatments in consecutive years. The fruits were stored at 40° F., and were examined in early January. The results are summarized in table 1.

TABLE 1. EFFECT OF LIMB AND FRUIT TREATMENTS ON SCALD, RHODE ISLAND GREENING

Tree	Treatment	Scald after storage			Scald after 2 days		
		Slight	Severe	Total	Slight	Severe	Total
		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
1941-42 season							
1	Normal	14.40	85.60	100.0	0	100.0	100.0
1	Defoliated	39.69	60.31	100.0	0	100.0	100.0
1	Limb shaded	26.50	73.50	100.0	0	100.0	100.0
1	Fruit shaded (white)	59.45	40.55	100.0	0	100.0	100.0
2	Normal	35.59	64.61	100.0	0	100.0	100.0
2	Defoliated	33.33	66.67	100.0	0	100.0	100.0
2	Limb shaded	0.00	97.91	97.91	0	100.0	100.0
2	Fruit shaded (white)	17.65	79.41	97.06	0	100.0	100.0
Average	Normal	....	....	100.0±0.0	....	....	100.0±0.0
Average	Defoliated	....	....	100.0±0.0	....	....	100.0±0.0
Average	Limb shaded	....	....	98.90±0.7	....	....	100.0±0.0
Average	Fruit shaded (white)	....	....	98.53±0.9	....	....	100.0±0.0
1942-43 season							
1	Normal	21.42	0	21.42	50.0	1.56	51.56
1	Limb shaded	13.33	0	13.33	40.29	2.98	43.27
2	Normal	20.68	55.17	75.85	19.64	80.35	99.99
2	Defoliated	0	0	0	6.89	0	6.89
2	Limb shaded	10.93	0	10.93	41.53	4.61	46.14
Average	Normal	....	....	48.63±18.3	....	....	75.77±16.3
Average	Defoliated	....	....	0	....	....	6.89
Average	Limb shaded	....	....	12.13±0.8	....	....	44.70±0.96

It may be seen in table 1 that scald was severe and differences between treatments were small and insignificant during the 1941-42 season. During the 1942-43 season it is apparent that defoliation decreased scald on the fruits from the one tree on which it was practiced. Limb-shading seemed also to reduce scald. It should be noted however, that the effects of limb-shading are complicated by the fact that these fruits shrivel very badly in storage. Scald is usually less on shriveled fruits, and hence the effect on scald may be indirect.

Rhode Island Greening, 1943-44. The 1943-44 results may be seen in table 2. During this season the fruits were stored at 32° F. until mid-February. The trees used during this season were not the same ones that were used in the two previous years. It would seem that limb-shading with cheesecloth had somewhat reduced the total amount of scald. However, the shriveling factor noted above should be considered in interpreting this difference. The white fruit shades resulted in more scald after storage, but the difference after standing seven days at room temperature was not significant. Use of black fruit shades (on one tree only) did not result in increased scald. On the average, defoliation seemed to reduce the amount of scald.

TABLE 2. EFFECT OF LIMB-SHADING AND DEFOLIATION ON SCALD, RHODE ISLAND GREENING, 1943-44

Tree	Treatment	Scald after storage			Scald after 7 days		
		Slight	Severe	Total	Slight	Severe	Total
		<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
3	Normal	38.77	14.28	53.05	20.40	73.46	93.86
3	Limb shaded	15.78	47.36	63.14	31.57	63.15	94.72
3	Fruit shaded (white)	19.29	80.70	99.99	3.50	96.49	99.99
3	Defoliated	30.76	7.69	38.45	53.84	30.76	84.60
4	Normal	40.57	21.73	62.30	33.33	65.21	98.54
4	Limb shaded	37.50	34.47	71.87	25.00	71.87	96.87
4	Fruit shaded (white)	46.34	26.82	73.16	29.26	58.53	87.79
4	Fruit shaded (black)	50.00	12.50	62.50	29.16	62.50	91.66
4	Defoliated	45.45	13.63	59.08	31.81	68.18	99.99
5	Normal	50.00	7.69	57.69	30.76	52.56	83.32
5	Limb shaded	0	0	0	47.36	0	47.36
5	Fruit shaded (white)	47.50	17.50	65.00	22.50	75.00	97.50
5	Defoliated	0	0	0	22.22	3.70	25.92
6	Normal	42.30	44.23	86.53	11.53	84.61	96.14
6	Limb shaded	29.03	29.03	58.06	12.90	77.41	90.31
6	Fruit shaded (white)	41.17	47.05	88.22	24.47	75.52	99.99
6	Defoliated	7.14	0	7.14	64.28	21.42	85.70
7	Normal	51.11	15.55	66.66	17.77	75.55	93.32
7	Limb shaded	13.79	86.20	99.99	0	100.00	100.00
7	Fruit shaded (white)	20.45	45.45	65.90	27.27	65.90	93.17
7	Defoliated	21.87	6.25	28.12	50.00	9.37	59.37
Average	Normal	.....	.....	64.24 ± 3.9	.....	.....	93.08 ± 1.8
Average	Limb shaded	.....	.....	58.60 ± 11.0	.....	.....	67.85 ± 8.9
Average	Fruit shaded (white)	.....	.....	78.44 ± 4.6	.....	.....	95.68 ± 4.98
Average	Fruit shaded (black)*	.....	.....	62.50	.....	.....	91.66
Average	Defoliated	.....	.....	38.86 ± 8.3	.....	.....	71.11 ± 8.15

*One tree only.

McIntosh. Limb treatments similar to those for Greening were made on McIntosh trees about 20 years old for three years. These apples were all stored at 32° F. and examined in April or May.

Results for the 1941-42 season are given in table 3. Differences were small. The large amount of scald on one shaded limb (tree 32-1-8) made the average scald higher on shaded limbs, but this difference is not significant.

Results for the 1942-43 season also are shown in table 3. More trees were used during this season. It is apparent from the average amounts of scald that limb-shading reduced the amount of scald. This is in accord with the results on Greening. Fruits shaded with white shades had an increased amount of scald. This was noted on Greening also. Black fruit shades (one tree only) resulted in less scald than occurred on normal fruits from the same tree. However, so few fruits were used with these black shades that no conclusions should be drawn from the results.

Data for the 1943-44 season are given in table 3. In this season the effect of limb-shading on scald was variable, and there was no significant effect. Individual white fruit shades seemed to reduce the amount of scald. This is in contrast with the previous year's results. On the average, defoliation seemed to decrease the amount of scald. This decrease was noted on all trees. This effect is in accord with that noted on Greening.

TABLE 3. EFFECT OF LIMB TREATMENTS ON SCALD, McINTOSH

Tree	Treatment	Scald after storage (per cent)	Tree	Treatment	Scald after storage (per cent)
1941-42			1943-44		
32-1-8	Normal	0.78	32-3-8	Normal	50.76
32-1-8	Defoliated	0	32-3-8	Limb shaded	43.66
32-1-8	Limb shaded	12.0	32-3-8	Fruit shaded (white)	16.66
			32-3-8	Defoliated	8.57
32-4-9	Normal	0	32-5-4	Normal	7.04
32-4-9	Defoliated	0	32-5-4	Limb shaded	33.33
32-4-9	Limb shaded	0	32-5-4	Fruit shaded (white)	2.63
32-4-11	Normal	0.85	32-5-4	Defoliated	0
32-4-11	Defoliated	2.2			
32-4-11	Limb shaded	0	32-7-2	Normal	64.51
Average	Normal	0.54 ± 0.18	32-7-2	Limb shaded	84.61
Average	Defoliated	0.70 ± 0.49	32-7-2	Fruit shaded (white)	20.93
Average	Limb shaded	4.0 ± 2.7	32-7-2	Defoliated	22.22
1942-43					
32-4-15	Normal	100.0	32-3-6	Normal	50.00
32-4-15	Limb shaded	2.77	32-3-6	Limb shaded	6.66
32-4-15	Fruit shaded (white)	80.00	32-3-6	Fruit shaded (white)	8.57
32-4-15	Fruit shaded (black)	63.63	32-3-6	Defoliated	16.66
			32-3-6	Fruit shaded (black)	25.00
32-3-18	Normal	5.76			
32-3-18	Limb shaded	9.61	32-6-3	Normal	28.94
32-3-18	Fruit shaded (white)	55.0	32-6-3	Limb shaded	3.84
32-4-19	Normal	38.18	32-6-3	Fruit shaded (white)	0
32-4-19	Limb shaded	9.43	32-6-3	Defoliated	21.87
32-4-19	Fruit shaded (white)	66.66			
32-3-22	Normal	16.66	32-5-6	Normal	30.43
32-3-22	Limb shaded	6.66	32-5-6	Limb shaded	50.00
32-3-22	Fruit shaded (white)	82.35	32-5-6	Fruit shaded (white)	0
			32-5-6	Defoliated	2.43
32-4-13	Normal	24.75			
32-4-13	Limb shaded	8.16	Average	Normal	38.61 ± 5.5
Average	Normal	17.81 ± 12.9	Average	Limb shaded	37.01 ± 3.0
Average	Limb shaded	7.32 ± 0.84	Average	Fruit shaded (white)	8.13 ± 2.0
Average	Fruit shaded (white)	71.00 ± 4.28	Average	Defoliated	11.95 ± 2.6

EFFECT OF NITROGEN FERTILIZATION

Rhode Island Greening. Several trees in two orchards of Rhode Island Greening were treated with nitrogen. Similar trees in the same orchards were left unfertilized. The trees in orchard 33 were about 10 years old when first treated in 1941, and those in orchard A were about 16. These trees were all growing normally before treatments were begun, but were beginning to show signs of nitrogen deficiency. They had previously been unfertilized for a number of years but had been cultivated periodically.

The trees in orchard 33 were treated with 2.5 pounds of Uramon (42 per cent nitrogen) in June and again in July each year. The trees in orchard A were treated with 5 pounds of Uramon in June and again in July. No treatments were made during 1942 because of the extremely light crop.

To equalize crop size in every instance the trees were thinned each year so that both the treated and the untreated trees had approximately the same-sized crop per tree. In 1941-42 the fruits were stored at 40° F., but in 1943-44 they were stored at 32° F.

It will be noted in tables 4 and 5 that new trees were selected in some instances for treatment during the second year, so that in most instances the fruit shows the effects of only one year of fertilization with nitrogen. During 1941 two harvests were made from some of the nitrogen-treated trees.

TABLE 4. EFFECT OF NITROGEN FERTILIZATION ON SCALD, RHODE ISLAND GREENING, 1941-42

Tree	Treatment	Harvest date	Scald after storage*			Scald after 9 days		
			Slight	Severe	Total	Slight	Severe	Total
			Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Orchard 33								
33-20	Normal	9/5/41	5.88	94.11	100.00	0	100	100
33-21	Normal	9/5/41	6.25	93.75	100.00	0	100	100
33-22	Normal	9/5/41	31.52	68.48	100.00	0	100	100
33-23	Normal	9/5/41	16.67	83.33	100.00	0	100	100
33-24	Normal	9/5/41	3.45	96.55	100.00	0	100	100
33-25	Normal	9/5/41	19.12	75.74	94.06	0	100	100
Average...					99.13 ±0.67			100.00
33-1	Nitrogen	9/5/41	30.25	63.03	93.28	0	100	100
33-2	Nitrogen	9/5/41	7.83	83.49	91.31	0	100	100
33-3	Nitrogen	9/5/41	32.35	41.91	74.26	0	100	100
33-4	Nitrogen	9/5/41	23.33	76.67	100.00	0	100	100
33-5	Nitrogen	9/5/41	35.06	35.06	70.12	0	100	100
Average...					85.79 ±3.97			100.00
Orchard A								
A-O' 14	Normal	9/10/41	31.06	68.94	100.00	0	100	100
A-P' 16	Normal	9/10/41	51.08	34.53	85.61	0	100	100
A-O' 11	Normal	9/10/41	21.43	78.57	100.00	0	100	100
A-P' 17	Normal	9/10/41	9.56	78.68	88.24	0	100	100
Average...					93.46 ±2.7			100.00
A-O' 7	Nitrogen	9/10/41	37.50	40.63	78.13	0	100	100
A-O' 8	Nitrogen	9/10/41	27.15	59.60	86.75	0	100	100
A-O' 9	Nitrogen	9/10/41	35.61	64.39	100.00	0	100	100
Average...					88.29 ±4.3			100.00

*1/10/42.

The 1941-42 results may be seen in table 4. Upon examination after storage there actually seemed to be less total scald on the nitrogen-treated fruits than on the untreated in orchard 33. When examined after nine days, all lots were affected 100 per cent with severe scald. On the basis of this year's data it can be safely said that fertilization with nitrogen did not increase scald even though the treated trees had darker green foliage. Firmness data are not included in this table, but it was apparent from pressure tests that nitrogen-treated fruits were, on the average, two pounds softer, as measured by the pressure tester at harvest time. Yet there was no real difference in the amount of scald.

The 1943-44 results are given in table 5. When examined after harvest it was apparent that differences in the amount of total scald were not large, on the average. Although there was slightly less scald, on the average, on the nitrogen-treated fruits, the difference was very small and insignificant. When examined after seven days at room temperature the same trend was noted, but the differences are not significant. Again, it would seem safe to say that summer fertilization with nitrogen did not increase the amount of scald. Pressure-test data at harvest time indicated, however, that the fruits in orchard 33 were 1.0 pound softer, and in orchard A, 0.7 pound softer, as a result of nitrogen fertilization.

TABLE 5. EFFECT OF NITROGEN FERTILIZATION ON SCALD,
RHODE ISLAND GREENING, 1943-44

Tree	Treatment	Scald after storage*			Scald after 7 days		
		Slight	Severe	Total	Slight	Severe	Total
		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Orchard 33							
33-11	Normal	47.45	16.94	64.39	18.64	77.96	96.60
33-12	Normal	20.00	45.00	65.00	16.66	81.66	98.32
33-13	Normal	39.21	15.68	54.89	37.25	60.78	98.03
33-14	Normal	39.28	48.21	87.49	5.37	94.64	100.00
33-15	Normal	5.55	5.55	11.00	41.66	19.44	61.10
Average . . .				56.55 ± 8.49			90.81 ± 2.63
33-1	Nitrogen	50.00	0	50.00	53.57	42.85	96.42
33-2	Nitrogen	19.23	38.4	57.63	29.82	40.35	70.17
33-3	Nitrogen	62.79	30.23	93.02	55.76	28.84	84.60
33-4	Nitrogen	20.58	2.94	23.52	58.82	17.64	76.46
33-5	Nitrogen	38.88	11.11	49.99	38.88	61.11	99.99
Average . . .				54.83 ± 7.5			85.53 ± 3.77
Orchard A							
A-O-13	Normal	50.00	10.00	60.00	15.00	80.00	95.00
A-O'-10	Normal	54.34	6.52	60.86	0	100.00	100.00
A-O'-11	Normal	5.26	85.96	91.22	7.01	92.98	99.99
A-P'-16	Normal	26.66	5.00	31.66	45.00	13.33	58.33
Average . . .				60.93 ± 8.2			88.32 ± 10.1
A-0-5	Nitrogen	44.73	44.73	89.46	13.15	86.80	99.85
A-0-7	Nitrogen	48.27	13.79	62.06	55.17	44.83	100.00
A-0-8	Nitrogen	3.70	7.40	11.10	25.92	3.70	26.62
A-0-9	Nitrogen	36.58	26.82	63.40	14.63	80.48	95.11
Average				56.50 ± 11.0			81.18 ± 11.46

*2/15/44.

Urea spray. During the 1943 growing season, individual limbs of six Rhode Island Greening trees were sprayed with a solution of pure urea (1 pound to 50 gallons of water) according to the method of Hamilton, Palmer, and Anderson (1943). Two sprays were applied at weekly intervals during mid-July. The trees were at a moderate nitrogen-nutrition level.

The fruits from these limbs and from unsprayed limbs of the same trees were composited. All fruit was stored at 32° F.

TABLE 6. EFFECT OF UREA SPRAYS DURING SUMMER ON SCALD, RHODE ISLAND GREENING

Treatment	Scald after storage			Scald after 3 days		
	Slight	Severe	Total	Slight	Severe	Total
Normal.....	<i>Per cent</i> 24.56	<i>Per cent</i> 71.92	<i>Per cent</i> 96.48	<i>Per cent</i> 1.75	<i>Per cent</i> 98.24	<i>Per cent</i> 99.99
Urea.....	23.25	76.74	99.99	0	100.00	100.00

In table 6 it is shown that these two urea sprays had no effect on the amount of scald on these Greening fruits. It is not likely that large amounts of nitrogen were added in this way, but the fruits from the urea limbs did have a significantly faster respiration rate after harvest. These data will be presented in a separate report. The data more or less confirm those on nitrogen applications to the soil in regard to both scald and effects on respiration and firmness of fruit. It should be noted however, that in no instance did nitrogen treatments result in high nitrogen-nutrition levels in the trees.

EFFECT OF THIOCYANATE SPRAYS

Dustman and Duncan (1940) have suggested that spraying with thiocyanate sprays would reduce the scald on some varieties.

An experiment was conducted during the 1941-42 season with Rhode Island Greening apples. Uniform ten-year-old trees were selected; six trees were sprayed and six were left unsprayed. In the first spray with sodium thiocyanate a 0.05-per-cent dilution was used. A second application of 0.1 per cent was made on August 4, and a third of 0.05 per cent on August 18. By harvest time there was a rather severe foliage injury. There were smaller amounts of soluble solids in the sprayed fruits, which probably resulted from the foliage injury. These fruits were stored at 40° F.

It seemed from the development in ground color that the spraying hastened maturity. There was distinctly more red color on the sprayed fruits, as has been reported by Dustman and Duncan. Data are not presented, but the scald data show that the spraying did not reduce the total amount of scald although it did reduce the severity slightly. There was 100 per cent scald on both the sprayed and the unsprayed lots. The reduction in scald might be attributed to the advanced maturity of these fruits, although the reduction was not significant.

The severe foliage injury would preclude the use of this spray on this variety even though it might reduce the scald in some years.

SEASONAL VARIATION IN SCALD SUSCEPTIBILITY AND
VOLATILE PRODUCTION

Fruit growers are well aware that apples are very susceptible to scald in storage some years and not in others. To illustrate this point, the amount of scald on the same Greening and McIntosh trees was recorded over a period of three years. The fruits were picked each year at as nearly the same degree of maturity as possible. Crop size was more or less uniform each year. The fruits from the Greening trees were stored at 40° F., and the McIntosh fruits at 32° F.

Results on the Greening fruits are given in table 7, and on the McIntosh in table 8.

Severity may vary for a number of reasons. One factor that probably determines susceptibility is climate. With data for so few years it would not be safe to draw broad conclusions on climatological relations to scald

TABLE 7. SEASONAL FLUCTUATIONS IN SCALD ON GREENING APPLES

Tree	Scald after storage			Scald after 2 days		
	Slight	Severe	Total	Slight	Severe	Total
	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
1/10/42						
1.....	14.40	85.60	100.0	0	100.0	100.0
2.....	35.59	64.41	100.0	0	100.0	100.0
1/11/43						
1.....	21.42	0	21.42	50.00	1.56	51.56
2.....	20.68	55.17	75.85	19.64	80.35	99.99
1/15/44						
1.....	40.05	55.48	95.53	0.7	99.30	100.0
2.....	47.34	43.58	90.92	0	100.00	100.0

TABLE 8. SEASONAL FLUCTUATION IN SCALD ON MCINTOSH APPLES

Harvest date	Pressure	Ground color*	Total scald after storage (May 1)
	<i>Pounds</i>		<i>Per cent</i>
1941-42			
9/17/41.....	16.0	2½-3	100.00
9/24/41.....	15.28	2½-3	100.00
10/1/41.....	12.7	3	100.00
10/9/41.....	13.36	4	100.00
1942-43			
9/17/42.....	16.8	2½-3	80.00
9/24/42.....	17.3	3	90.00
10/1/42.....	15.5	3-4	70.00

*1 indicates a dark green on the ground-color chart; 4, a rather fully developed yellow.

intensity. It was observed, however, that the growing season of 1942 was cooler and cloudier than that of the year before or of the year after. Scald was somewhat less in this particular year. While crop size was more or less constant during the three years of this experiment there were probably small differences that might well account for variations in scald susceptibility. Rainfall might have some effect, but this factor was not studied.

The work of Brooks, Cooley, and Fisher (1919b) showed that accumulations of volatiles seemed to cause scald. Hence, an attempt was made to measure variations in volatile production of McIntosh to see if there was a relation to scald intensity. McIntosh volatiles were measured because scald was observed on this variety, and also because it has been shown in this study that McIntosh vapors might induce increased scald on Greening apples.

Results of volatile measurements are shown in figure 2. In interpreting this figure it should be remembered that the particular fraction of these

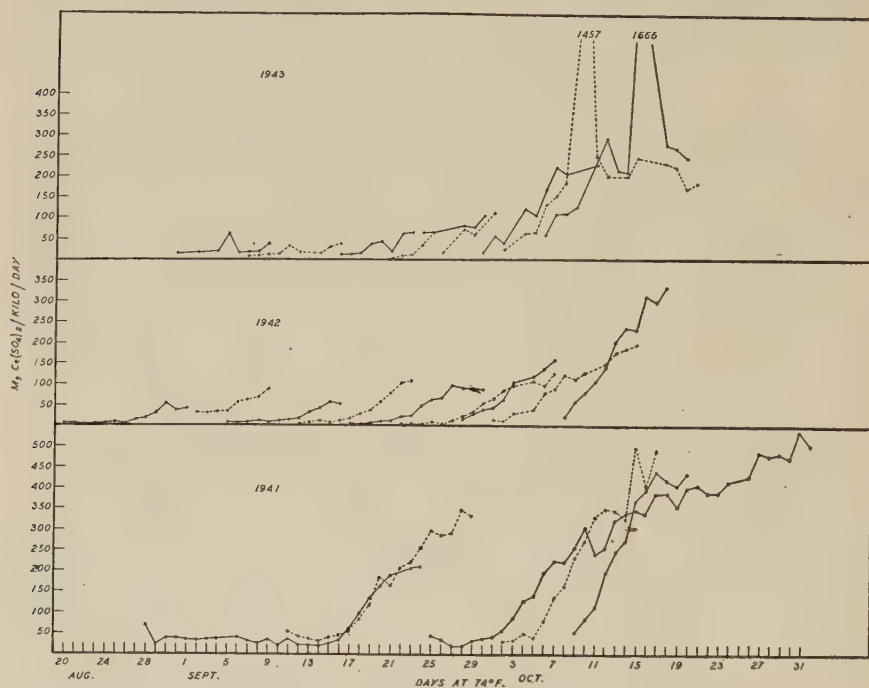


FIGURE 2. PRODUCTION OF TOTAL VOLATILE MATERIALS FROM MCINTOSH APPLES HARVESTED AT DIFFERENT DATES DURING A THREE-YEAR PERIOD

total volatiles responsible for scald is not known; also, ethylene production is not measured. However, it is most unlikely that ethylene production would vary from year to year differently from the total production of volatiles, although there is no proof of this assumption.

Apples from the same six McIntosh trees were composited at various picking dates for three years, and total volatiles were measured at 74° F. The general level of volatile production was considerably higher at all

picking dates in 1941 than in 1942 (figure 2). Except for the last two picking dates in 1943, the general level of volatile production was not greatly higher in that year than in 1942. The results for the last two pickings, however, show a very high production.

Scald intensity was lowest in 1942, during the year of lowest volatile production, although this may have been only a coincidence.

More study is needed on this point of scald variation from year to year. It may be found that it is not only a question of greater production of volatiles during some years but also of difference in susceptibility.

PRESTORAGE FACTORS THAT AFFECT SCALD

EFFECT OF FRUIT MATURITY

Various investigators — Brooks, *et al.* (1919a and b), Savage (1941), Christopher (1941) — have shown that scald was more likely to occur on early-picked fruits than on late-picked ones. This phase of the study was conducted to show the relation of scald to definite maturity standards at the time of harvest. In table 9 is shown the effect of maturity at harvest time of the fruit on the development of scald in storage.

Fruit was picked at weekly intervals during a seven-year period, and stored at 40° F. The fruit was not from the same trees each year; hence seasonal variations should not be studied in this table. The fruit was examined in late January for scald.

It is clear (table 9) that scald became less severe as the picking date was delayed. Delayed picking hardly seems to be the solution to the scald problem, however. In some years scald was of some magnitude on even the last-picked Rhode Island Greening fruit. This variety is sold as a green cooking apple, and if allowed to mature on the tree until it has a light-yellow ground color it does not bring a premium price as a cooking apple. Also, it is more subject to mealy breakdown if allowed to become more mature.

Cortland fruits can be allowed to mature longer on the tree to increase their resistance to scald. It is not necessarily possible to let them mature enough to escape scald. If this variety becomes too ripe on the tree, it is subject to internal breakdown in storage.

FRUIT TREATMENTS AFTER HARVEST

Brooks, Cooley, and Fisher (1923) proved the value of paper wraps or shreds of paper impregnated with mineral oil as a control measure for apple scald. They also tested wax and oil coverings on the fruit. These latter proved of no practical value in their tests. Since those tests were made, wax emulsions for fruits have been developed, and have proved valuable from the standpoint of checking moisture loss.

In this study with Rhode Island Greening some of these wax emulsions were tested as to their ability to check storage scald. In an earlier report (Smock, 1940) the results from use of a number of these waxes were given. It was shown that the effect of a wax coating on intensity of scald depended upon the nature of the emulsion, the concentration of the emulsion, and the maturity of the fruit. Some emulsions actually increased the intensity of scald. Since the publication of that report, several new waxes have been

TABLE 9. EFFECT OF MATURITY AT HARVEST TIME ON DEVELOPMENT OF STORAGE SCALD AT 40° F.

Pick- ing date	Greening					Cortland				
	Pressure test at harvest	Ground color at harvest	Soluble solids at harvest	Days from full bloom	Scald	Pressure test at harvest	Ground color at harvest	Soluble solids at harvest	Days from full bloom	Scald
	Pounds		Per cent		Per cent	Pounds		Per cent		Per cent
1937-38										
9/8	26.3	1½	9.5	107	92	...	...	...	...	..
9/20	23.3	2	10.9	117	89	...	...	...	...	..
9/30	22.2	2	11.5	127	0	...	...	...	...	..
10/9	19.3	2	12.2	136	2.2	...	...	...	...	..
1938-39										
9/1	24.0	1½	11.4	118	86	16.4	1½	11.1	122	59
9/8	24.8	1½	11.5	125	84	16.9	2	11.2	129	58
9/15	21.0	2	11.2	132	4	17.5	2½-3	11.5	136	55
9/22	21.8	2½	12.3	139	43	15.3	3	11.8	143	40
10/1	...	...	...	...	..	15.2	3½-4	13.0	152	10
1939-40										
9/2	22.8	1½-2	9.6	114	69	21.3	2	11.0	114	97
9/9	22.0	1½-2	10.6	121	77	19.0	2½	11.2	121	88
9/16	21.8	2	10.8	128	71	19.2	2½	11.2	128	61
9/23	21.1	2	11.3	135	74	17.6	2½-3	12.0	135	24
10/2	20.8	2-2½	13.0	144	23	15.3	4	12.6	144	3
1940-41										
9/9	26.8	1½-2	12.2	108	83	19.8	2	12.2	108	21
9/16	25.8	1½-2	11.2	115	94	16.3	2	11.5	115	8
9/23	26.3	1½-2	10.8	122	75	15.9	2½	11.7	122	8
9/30	25.6	2	12.1	129	39	15.7	2-2½	11.9	129	2
10/7	24.1	2	11.5	136	3	16.4	2½-3	12.2	136	8
1941-42										
9/1	26.4	1½	10.4	119	100	...	...	...	...	..
9/8	26.8	2	10.4	126	100	18.1	3	10.6	122	95
9/15	25.5	2	10.6	133	98	16.9	3	11.4	129	100
9/22	23.1	1½	11.4	140	100	...	3½	12.2	136	..
10/6	20.8	2	11.8	154	89	15.2	3-4	12.8	150	40
1942-43										
9/1	27.1	1½	9.2	119	100	...	...	...	...	..
9/8	26.3	1½-2	9.2	126	100	19.5	2	11.0	128	43
9/15	24.4	1½	9.6	133	59	20.3	2	11.0	135	27
9/22	25.3	1¾	12.0	140	55	20.8	2¾	11.6	142	8
9/30	25.0	1¾	10.0	147	45	19.8	2¾	12.8	149	0
10/7	22.6	1¾	11.8	154	18	16.5	3	11.8	156	0
1943-44										
9/8	29.2	1½	10.6	106	90	...	...	...	...	..
9/15	27.6	2	11.2	113	85	...	...	...	...	..
9/22	26.7	2½	11.0	120	59	19.4	2½	13.1	121	0
9/29	24.5	2½	11.4	127	60	18.1	3	13.1	128	3
10/6	24.1	2½	12.4	134	5	17.6	3-4	14.2	135	0.8

tested. These were prepared through the cooperation of the Franklin Research Company. In recent years a mineral-oil coating that has been on the market has been recommended for control of apple scald. This material was tested also.

Shredded oiled paper (one-half pound per bushel) was used in these tests as a basis of comparison. This material, while not a perfect scald-control measure, has been recognized as the best method of control to date.

With but one or two exceptions, all treatments in these trials consisted of two-bushel lots. During two seasons of this four-year experiment, one lot of fruit was given a delayed-storage treatment. This consisted of leaving the fruit on the packing-house floor in a spot where it would get good ventilation. One-half of this delayed-storage lot was then waxed as suggested by Hitz and Haut (1941). During three of the four seasons the apples were picked at two or three dates.

The apples were stored at 32–34° F. with other varieties during the storage season. They were examined for scald immediately after storage, and again after standing at room temperature for several days.

Oiled paper. Shredded oiled paper gave the most consistent reduction in scald during this four-year test on Rhode Island Greening (tables 10–13). It should be noted, however, that it cannot be considered a perfect control measure on this variety, especially on the earlier pickings. Objections to the use of this material appear under the heading *Discussion and Practical Considerations*, page 31.

Wax 489 AM. This wax emulsion gave results on scald reduction (tables 10–13) that approximated those of oiled paper. On the extremely early pickings it was not so effective in reducing scald as was shredded oiled paper, but on the later pickings it was just about as effective as was the oiled paper. It had the advantage over oiled paper in that it reduced shriveling, and left the fruit greener, firmer, and generally more attractive than did the oiled paper.

A concentration of 8.5 per cent solids in the emulsion, usually but not always, gave somewhat better results in scald control than did one of 4.25 per cent solids. In some years it would not have paid to have used the more concentrated emulsion, however.

Other waxes. Several other waxes not hitherto reported on were included in these tests. Wax 489 MM gave but little better results during a one-year trial than did 489 AM.

Wax 489 A has been reported upon before (Smock, 1940), but it was included in this investigation as a basis of comparison since it is the apple wax recommended for use by one wax manufacturer. The previous studies and this one showed that this wax had little or no scald-reducing capacity.

Wax 929 A was tried for two years, and it is indicated in tables 11 and 12 that it has some scald-reducing power. This wax left the fruit rather dull-looking because of its high mineral oil content. It was not enough better than 489 AM to justify its use from the scald standpoint.

Mineral oil. This material was not a highly refined white mineral oil, but a commercial grade that has been put on the market for scald control. It is sprayed on the fruit as a fine mist. During the first season of the test (table 10) it gave no scald control. During the second season (table 11) the material was sprayed on in a "light" application and in a "heavy" application. In the latter instance the fruit was almost dripping with mineral oil. Neither type of application gave any appreciable reduction in scald. In the third season (table 12) this material gave a considerable reduction in scald. In fact, during this season it gave as good as or better control than did oiled paper. No explanation seemed evident for this lack of consistency in results. It was thought that the variation in results obtained from year to year might have been due to the temperature of the fruit at the time of treatment.

TABLE 10. EFFECT OF WAXES ON SCALD, RHODE ISLAND GREENING
STORED AT 32-34° F. (1940-41)

Treatment	Solids in wax	Scald after storage 3/8/41			Scald after 7 days at room temperature		
		Slight	Severe	Total	Slight	Severe	Total
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Harvested 9/16/40							
Untreated.....	...	48.4	41.6	90.0	14.1	82.6	96.7
Oiled paper.....	...	22.4	4.1	26.5	10.8	20.2	31.0
Mineral oil.....	...	30.9	48.6	79.5	17.0	64.4	81.4
489A.....	8.50	41.7	34.1	75.8	23.0	65.4	88.4
489 AM.....	4.25	28.9	31.1	60.0	22.0	47.9	69.9
Delayed 1 week.....	...	40.2	20.8	61.0	9.7	72.7	82.4
Delayed 1 week then 489A..	8.50	60.0	4.3	64.3	24.3	65.9	93.8
Harvested 9/26/40							
Untreated.....	...	1.2	...	1.2	54.3	0	54.3
Mineral oil.....	...	34.9	14.2	49.1	44.6	44.2	88.8
489 A.....	8.50	0	0	0	71.4	2.7	74.1
489 A.....	4.25	0	0	0	73.5	7.5	81.0
489 AM.....	8.50	0	0	0	5.0	0	5.0
489 AM.....	4.25	0	0	0	29.8	0	29.8
661.....	8.50	0	0	0	40.9	4.4	45.3
661.....	4.25	...	...	...	30.4	12.4	42.8
816 A.....	8.50	...	...	...	40.2	38.3	78.5
816 A.....	4.25	4.0	0	4.0	73.6	0	73.6
Oiled paper.....	...	0	0	0	6.7	1.7	8.4
Harvested 10/3/40							
Untreated.....	...	0	0	0	28.5	1.3	29.8
Oiled paper.....	...	1.7	0	1.7	1.7	1.8	3.5
Mineral oil.....	...	9.2	1.4	10.6	19.8	28.1	47.9
489 A.....	8.50	0	0	0	1.2	8.4	9.6
489 A.....	4.25	1.7	1.1	2.6	34.6	1.7	36.3
489 AM.....	8.50	1.4	0	1.4	4.7	0	4.7
489 AM.....	4.25	1.1	0	1.1	1.0	3.6	4.6

Hence, in the fourth season (table 13), one lot of fruit was treated at normal outside temperatures (about 65° F.), and another lot was cooled down to 40° F. before treatment. The warm-mineral-oil treatment gave slightly better results than did the cold treatment. The difference was small, however, and it was not known whether this would account for the seasonal fluctuation in results. During the fourth year, this material gave some reduction in scald but was not so good as oiled paper or as wax 489 AM (8.5 per cent solids).

Delayed storage. During the first season one lot of apples was allowed to stand on the packing house floor for one week before storage. Another lot was waxed with 489 A after this period of delay, as suggested by Hitz and Haut (1941). The period of delay resulted in slightly less scald, but there seemed to be no additional scald control because of waxing.

During the second season one lot of fruit was delayed 13 days before storage, and a second lot was waxed with 489 AM after the period of delay. This was done at two harvest dates (table 11). The first-picked fruit had considerably less scald as a result of the period of delay but there seemed to be no added advantage in waxing from the standpoint of scald. The second-picked fruit showed considerably less scald as a result of the period of delay, and the wax seemed to cut the scald still further. In fact, the intensity of scald was least after this treatment during this particular year.

TABLE 11. EFFECT OF WAXES ON SCALD, RHODE ISLAND GREENING
STORED AT 32-34° F. (1941-42)

Treatment	Solids in wax	Scald after storage 3/6/42			Scald after 7 days at room temperature		
		Slight	Severe	Total	Slight	Severe	Total
	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
Harvested 9/11/41							
Untreated.....	...	23.60	40.00	63.00	24.56	66.67	91.23
Oiled paper.....	...	3.79	0.68	4.47	25.78	1.56	27.34
Light application mineral oil.....	...	58.10	10.67	68.77	25.67	74.32	99.99
Heavy application mineral oil.....	...	8.26	0.80	9.06	42.37	22.88	65.25
489 A.....	8.50	45.60	22.40	68.00	29.05	70.94	99.99
489 A.....	4.23	59.83	11.64	71.47	19.59	80.41	100.00
489 AM.....	8.50	21.25	22.04	43.29	28.63	61.11	89.74
489 AM.....	4.25	1.96	0	1.96	40.97	37.56	78.53
929 A.....	8.50	20.1	0	20.1	46.44	34.59	81.03
929 A.....	4.25	29.95	19.30	48.25	54.20	45.80	100.00
Delayed 13 days.....	...	2.29	0.76	3.05	34.66	15.13	59.79
Delayed 13 days then 489 AM.....	8.50	0	0	0	47.16	4.36	51.52
Harvested 9/22/41							
Untreated.....	...	28.16	9.79	37.95	24.88	75.11	99.99
Oiled paper.....	...	12.60	3.65	16.25	59.02	6.34	65.36
Light application mineral oil.....	...	17.56	2.70	20.26	38.20	52.45	90.65
Heavy application mineral oil.....	...	7.55	2.22	9.77	92.39	7.61	100.00
489 A.....	8.50	21.91	26.94	48.85	31.77	54.16	85.93
489 A.....	4.25	14.93	14.52	29.45	45.24	53.39	98.63
489 AM.....	8.50	1.48	0.4	1.88	57.39	4.14	61.53
489 AM.....	4.25	1.32	0	1.32	55.43	3.26	58.69
929 A.....	8.50	3.66	0.91	4.77	53.76	5.91	59.67
929 A.....	4.25	0.44	0.44	0.88	48.29	1.95	50.24
Delayed 13 days*.....	...	0	0	0	34.0	2.0	36.0
Delayed 13 days then 489 AM*.....	8.50	0	0	0	7.0	0	7.0

*Spongy.

In another and separate experiment (data not presented) during the 1943-44 season, a delay period of nine days on Greening did not have a significant effect in reducing scald. However, Greening fruits subjected to this period of delay and then waxed with 489 AM, had 9 per cent total scald as against 71 per cent scald on the controls.

It would seem that delayed storage may significantly reduce scald on Greening in some seasons if ventilation is good during the period of delay. Waxing with 489 AM may still further decrease the amount of scald when practiced after the period of delay.

Delayed storage would seem to be a questionable practice with this variety because the apples ripen appreciably during the period of delay and they are sold as a green cooking apple. The apples not only yellow slightly but become somewhat spongy during the period of delay.

STORAGE CONDITIONS THAT AFFECT SCALD

INFLUENCE OF ONE LOT OF APPLES ON ANOTHER IN AIR STORAGE

A number of experiments were set up to determine the influence of one lot of apples on the scalding of a second lot in air storage. Usually a second variety was used; however, sometimes lots of the same variety but of different maturities were used. Unless otherwise indicated, two bushels of each lot were placed in separate, 55-gallon, gastight containers. Air was drawn

TABLE 12. EFFECT OF WAXES ON SCALD, RHODE ISLAND GREENING
STORED AT 32-34° F. (1942-43)

Treatment	Solids in wax	Scald after storage 1/29/43			Scald after 7 days at room temperature		
		Slight	Severe	Total	Slight	Severe	Total
Harvested 9/15/42							
Untreated.....	...	13.47	1.30	14.77	59.55	12.44	71.99
Oiled paper.....	...	10.60	0	10.60	35.68	5.63	41.31
Mineral oil.....	...	1.32	0	1.32	20.09	0.45	20.54
489 AM.....	8.50	20.52	1.05	21.57	46.93	20.40	67.33
489 AM.....	4.25	5.88	0	5.88	47.78	4.43	52.21
489 MM.....	8.50	16.83	0.99	17.82	47.24	6.03	53.27
489 MM.....	4.25	8.92	0	8.92	48.58	3.30	51.88
929 A.....	8.50	6.03	0	6.03	45.10	3.40	48.50
Harvested 9/28/42							
Untreated.....	...	0	0	0	19.58	2.06	21.64
Oiled paper.....	...	0	0	0	5.35	0	5.35
Mineral oil.....	...	0.91	0	0.91	3.73	0	3.73
489 AM.....	8.50	0	0	0	13.12	0	13.12
489 AM.....	4.25	0	0	0	12.82	0	12.82
489 MM.....	8.50	0	0	0	15.09	0	15.09
489 MM.....	4.25	0.46	0	0.46	14.67	0	14.67
929 A.....	8.50	0	0	0	11.11	0	11.11
929 A.....	4.25	0	0	0	19.81	0.94	20.75

TABLE 13. EFFECT OF WAXES ON SCALD, RHODE ISLAND GREENING
STORED AT 32-34° F. (1943-44)

Treatment	Solids in wax	Firm- ness	Scald after storage 3/7/44			Scald after 3 days at room temperature		
			Slight	Severe	Total	Slight	Severe	Total
	<i>Per cent</i>	<i>Pounds</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
Untreated.....	...	13.7	52.2	14.6	66.8	8.06	83.87	91.93
Oiled paper.....	...	14.8	14.6	10.0	14.6	37.70	18.90	52.60
Warm mineral oil.....	...	14.6	2.4	0	2.4	37.09	27.41	64.50
Cold mineral oil.....	...	14.8	5.1	0	5.1	45.60	32.00	77.60
489 AM.....	8.50	15.7	14.6	0	14.6	29.34	23.91	53.25
489 AM.....	4.25	15.8	25.8	0.7	26.5	23.80	51.58	75.38

by suction over the two lots of fruit. All air passed through water in bubbling bottles to humidify it. Various absorbents and adsorbents were put between the two chambers to see if the scald-stimulation effect could be reduced. During the 1941-42 season, outside air was not used as a source of air. Air during that season was passed through activated lignite charcoal before going to any chamber, but it proved of little value in decontaminating storage-room air of scald gases. Subsequent experiments used outside air unless otherwise indicated.

Effect of McIntosh on Cortland. During the 1941-42 season the vapors of McIntosh prime for storage were passed over prime Cortland at 40° F. The rate of air flow was 1.4 cubic feet per hour. Between the two varieties was placed 80 grams of activated lignite charcoal in one series. Between the two varieties of another series was placed a 23x1-inch column of glass beads, over which was poured 75cc. of Prorox F oil once a day. Results may be seen in table 14.

TABLE 14. EFFECT OF McINTOSH ON SCALD OF CORTLAND STORED AT 40° F. (1941-42)

Treatment	Scald after storage 1/8/42			Scald after 2 days at room temperature		
	Slight	Severe	Total	Slight	Severe	Total
	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
Cortland.....	29.0	0	28.0	0	98.2	98.2
McIntosh→Cortland.....	50.4	3.1	53.1	3.1	95.2	98.3
McIntosh→charcoal→Cortland.....	24.0	0	24.0	0	98.1	98.1
McIntosh→oil→Cortland.....	9.4	0	9.4	0	100.0	100.0

It may be seen that on examination after storage the McIntosh had almost doubled the amount of scald on Cortland. No difference was apparent after both lots had stood at room temperature for two days, however. On examination after storage it seemed that the charcoal had removed this effect of the McIntosh, but after two days no such result was apparent. When examined after storage, the oil seemed to have resulted in actually less scald than was present on the control. This could be explained only by the fact that outside air was not used and there were scald gases in the storage atmosphere being brought into these chambers. No such difference was apparent after two days, however.

Effect of McIntosh on Rhode Island Greening. 1. The last experiment was duplicated with Rhode Island Greening except that Oliva 34 oil was used. Results are given in table 15.

TABLE 15. EFFECT OF McINTOSH ON SCALD OF RHODE ISLAND GREENING STORED AT 40° F. (1941-42)

Treatment	Scald after storage 1/7/42			Scald after 1 day at room temperature		
	Slight	Severe	Total	Slight	Severe	Total
	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
Greening.....	57.0	0	57.0	19.6	80.3	99.9
McIntosh→Greening.....	69.2	19.2	88.3	0	98.1	98.1
McIntosh→charcoal→Greening.....	58.1	23.6	81.7	12.5	87.5	100.0
McIntosh→oil→Greening.....	50.0	14.3	64.3	12.2	87.5	99.7

It may be seen in table 15 that, upon examination after storage, the McIntosh had significantly increased the scald on the Greening. The lignite charcoal had no effect in this experiment, and the oil only partially reduced the McIntosh effect. No differences were apparent after the fruits had stood at room temperature for a day.

2. During the 1942-43 season, the effect of sun-colored McIntosh¹ on the scalding of Greening apples was studied. In this experiment, outside air was used. The oils and lignite charcoal were changed on November 4, 1942. The air flow was about one cubic foot per hour.

It is evident in table 16 that the vapors of the sun-colored McIntosh had increased the scald on the Greening. The difference was more obvious immediately after storage than after four more days at room temperature. It is apparent that lignite charcoal may have been of slight benefit. Neither

¹Fruit picked and placed under the tree to color for 10 days.

TABLE 16. EFFECT OF SUN-COLORED MCINTOSH ON SCALD OF RHODE ISLAND GREENING STORED AT 40° F. (1942)

Treatment	Scald after storage 12/7/42			Scald after 4 days at room temperature		
	Slight	Severe	Total	Slight	Severe	Total
	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
Greening→Greening.....	0.76	0	0.76	45.45	28.92	74.37
McIntosh→Greening.....	9.93	0.66	10.59	37.74	56.29	94.03
McIntosh→charcoal→Greening.....	6.34	0	6.34	55.17	31.03	86.20
McIntosh→A ₅ oil→Greening.....	9.17	0	9.17	39.51	45.16	84.67
McIntosh→I ₁ oil→Greening.....	11.03	3.44	14.47	27.08	68.75	95.83

oil seemed to be of any particular value, although there was a suggestion that the A₅ oil was slightly better than the I₁ oil.

3. During the 1943-44 storage season, experiment 2 was repeated; brominated activated carbon was used as an absorbent between the two chambers. In one series the air-conditioning tower contained 40 grams of activated cocoanut-shell carbon treated with 5cc. of bromine and 40 grams of plain activated carbon. The brominated carbon was replaced with freshly treated material at monthly intervals. In another series, the Greening were mixed with one-half pound of shredded oiled paper to see if this material would protect the Greening from McIntosh vapors.

TABLE 17. EFFECT OF SUN-COLORED MCINTOSH ON SCALD OF RHODE ISLAND GREENING STORED AT 40° F. (1943-44)

Treatment	Scald after storage 12/21/43	Scald after 3 days at room temperature		
	Total	Slight	Severe	Total
	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
Greening→Greening.....	31.0	20.0	42.8	62.8
McIntosh→Greening.....	76.0	19.2	73.0	92.2
McIntosh→oiled paper→Greening.....	0	48.0	8.0	56.0
McIntosh→brominated carbon→Greening.....	25.0	35.1	32.4	67.5

It may be seen in table 17 that the McIntosh vapors had doubled the scald upon removal from storage. The difference was not so great after three days at room temperature, although there was almost twice as much severe scald on the McIntosh-treated lot. The oiled paper seemed to protect the Greening apples from the McIntosh vapors. The brominated carbon also seemed to eliminate the effect of the McIntosh. Of course, this treatment would not have any effect on "self-induced" scald since the tower was between the McIntosh and the Greening, whereas the oiled paper was in the box with the Greening. The question arises here as to why the scald is so high in these lots of Greening, no matter what the treatment. Although no data are offered to substantiate the claim, observations in similar tests indicate that when the humidity is close to saturation, the scald incidence is likely to be high. The relative humidity was always very high in these chambers.

4. In this experiment in 1942-43, 4-liter containers were used, and the rate of air flow was 3 cubic feet per hour. Because of the small volume of

the containers, this meant forty displacements of air per hour, in contrast to one displacement every seven hours in experiments 2 and 3. Greening apples comparable to those in experiment 2 were used. McIntosh prime for storage and sun-colored McIntosh as well as ripe Greening were used as a source of apple emanations. In one series, 80 grams of lignite charcoal, on which an unknown amount of bromine had been adsorbed, was used as a scald-gas absorbent.

TABLE 18. EFFECT OF SUN-COLORED MCINTOSH, PRIME MCINTOSH, AND RIPE GREENING APPLES ON SCALD OF RHODE ISLAND GREENING (1942)*

Treatment	Scald after storage 12/16/42			Scald after 4 days at room temperature		
	Slight	Severe	Total	Slight	Severe	Total
	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
Greening→Greening.....	14.28	14.28	28.56	58.33	25.0	83.33
Ripe Greening→Greening.....	8.33	0	8.33	100.0	0	100.0
Prime McIntosh→Greening.....	8.33	25.0	33.3	83.33	10.66	99.99
Sun-colored McIntosh→Greening.....	30.7	23.0	53.70	69.22	30.76	99.98
McIntosh→brominated charcoal →Greening.....	0	0	0	0	0	0

*Very rapid air flow used.

It may be seen in table 18 that there was actually more scald on the control here with fast air movement than in experiment 2 with slow air movement. The only explanation for this would be the apparent difference in relative humidity in the two experiments. Practically all the scald on the control in this experiment occurred where apples touched each other or the sides of the chambers. There was always free water at these points. There was no free water in the chambers in the preceding experiments, although the humidity was very high. The significant thing is that scald was not controlled with the very fast air movement. The ripe Greening seemed to cause somewhat more scald at the final inspection than was apparent on the controls. At the inspection after storage, the sun-colored McIntosh seemed to have induced more scald than had the prime McIntosh. The prime McIntosh caused more scald than did the ripe Greening. The brominated lignite charcoal apparently controlled the induced scald. There was some bromine injury on the Greening apples, and for this reason few conclusions should be drawn from this experiment. There must have been free bromine around the Greening fruits. Complete scald control was not obtained in experiment 3, possibly because there was no free bromine around the Greening fruits.

5. In this experiment at 33° F., 60-apple lots of Greening were used in 5-gallon containers during the 1942-43 season. Only 6 sun-colored McIntosh were used as a source of emanations. One lot of sun-colored McIntosh was held in a chamber heated to 70° F. The emanations from these heated apples were passed over a lot of Greening for 20 days. The emanations from the lot of McIntosh held at 33° were supplied for 50 days. Air was drawn in from outdoors.

In table 19 it is shown that only 6 sun-colored McIntosh increased the scald somewhat. The difference was not apparent after three days of additional storage at room temperature, although there was more severe scald

TABLE 19. EFFECT OF SUN-COLORED MCINTOSH ON SCALD OF GREENING STORED AT 33° F. (1942)

Treatment	Scald after storage 12/28/42			Scald after 3 days at room temperature		
	Slight	Severe	Total	Slight	Severe	Total
	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
Greening.....	2.12	0	2.12	40.42	53.19	93.61
McIntosh at 33°→Greening.....	5.88	1.96	7.84	13.72	82.35	96.07
McIntosh at 70°→Greening.....	2.22	0	2.22	46.66	51.11	97.77

where the McIntosh were used. The vapors of McIntosh held at 70° F. apparently had no effect on the scald of Greening. This suggests that a type of volatile was emanated at 33° F. that was responsible for scalding Greening, although it should be remembered that volatiles from the 70° F. apples were supplied for only 20 days.

6. During the 1943-44 storage season, scald development was studied on 60-fruit lots of Greening at 32° F. Storage-room air was passed over all lots of fruit. This air was first passed through bubbling bottles. In one series, the storage-room air was first passed through a long tower of calcium chloride to test the effect of this material on the removal of volatiles in the storage air. In a second series, the column of calcium chloride was followed by a bubbling bottle to rehumidify the air. This would tend to indicate whether the effect of the calcium chloride was in the lowering of the relative humidity or in actual removal of volatiles from the storage-room air. In a third series, a tower containing 340 grams of brominated activated carbon (cocoanut-shell type) was placed between the bubbling bottle and the apples. This was done to try to reduce the effect of storage-room volatiles on the Greening. In a fourth series, a chamber containing about 100 sun-colored McIntosh was placed in front of the Greening fruits. In a fifth series, a tower of 40 grams of brominated activated carbon with 40 grams of plain activated carbon (changed once a month) was placed between the sun-colored McIntosh and the Greening.

It should be noted that the scald was severe on all lots of apples in spite of a fairly rapid flow of air (about 1 cubic foot per hour) over them. This may have been due partly to the high concentration of volatiles in the storage atmosphere. It may have been due also to the high relative humidity in the chambers. There was some water of condensation in all chambers. Similar

TABLE 20. EFFECT OF STORAGE-ROOM AIR AND OF MCINTOSH VAPORS ON SCALD DEVELOPMENT OF GREENING AT 32° F.

Treatment	Scald after storage			Scald after 3 days		
	Slight	Severe	Total	Slight	Severe	Total
	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
Water→Greening.....	18.64	74.57	93.21	0	100.0	100.0
Calcium chloride→Greening.....	36.66	51.66	85.32	0	100.0	100.0
Calcium chloride→water→Greening...	46.03	31.74	77.77	0	100.0	100.0
Water→brominated carbon→Greening	37.94	20.68	58.61	34.61	63.45	98.06
Water→McIntosh→Greening.....	31.74	63.49	95.23	0	100.0	100.0
Water→McIntosh→brominated carbon →Greening.....	46.98	17.30	64.28	78.84	17.30	96.14

apples in the room, but not enclosed in chambers, did not scald so severely.

Upon removal from storage there was a slight difference in the scald on the lots treated with air passed through calcium chloride. This material seemed to reduce the scald slightly; its effect was probably caused by removal of volatiles rather than lowering of the humidity in the chamber. Where the air was rehumidified after treatment there seemed to be slightly less scald than where it was not. Little attention should be given to humidity effects, however, because as stated above, all chambers had condensed water on their sides.

When the storage atmosphere was passed through brominated activated carbon, the amount of scald seemed to be considerably less. Scald could not be controlled in a setup such as this because the Greening vapors were not removed (except by aeration). Other experiments had shown that even with the use of outside air and very rapid air movement, scald could not be entirely controlled in these high-humidity chambers.

The use of McIntosh apples did not increase the amount of scald in this experiment. This was probably due to the fact that the storage-room air was already contaminated by the volatiles of several hundred bushels of McIntosh apples. The use of brominated activated carbon between the McIntosh and the Greening apples did reduce the scald appreciably. Of course, this material was removing storage-room volatiles as well as those from the experimental lot of McIntosh apples.

7. In this experiment, a semicommercial trial was made in which the effect of rather ripe Greening and prime McIntosh on scald of Rhode Island Greening was studied. The experiment was not strictly controlled in that there were variations in the size of the rooms and in the numbers of bushels of apples used in each room. All rooms were held at 40° F. and air circulation was provided by blower fans. The Greening fruits were all comparable at the start of the experiment. The results are open to criticism, however, in view of the variations noted.

TABLE 21. SEMICOMMERCIAL TRIAL OF EFFECT OF MCINTOSH AND RIPE GREENING APPLES ON SCALD OF GREENING STORED AT 40° F. (1941-42)

Treatment	Scald after storage 12/30/41			Scald after 6 days at room temperature		
	Slight	Severe	Total	Slight	Severe	Total
	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
Greening alone.....	0	0	0	23.0	0	23.0
Greening with ripe Greening.....	23.9	3.3	27.2	44.0	32.1	76.1
Greening with McIntosh.....	55.8	4.4	60.2	20.5	77.9	98.4

It is clear from table 21 that the ripe Greening fruits increased the scald on the prime Greening, and that the McIntosh had a still greater influence. In spite of the criticism of the experiment noted above, the general results seem valid in the light of better-controlled experiments.

8. Semicommercial tests were repeated during the 1943-44 storage season with Rhode Island Greening to test the effect of other lots of apples on scald development. An attempt was made also to control the scald by air-conditioning.

Three rooms were used in this test at 40° F. in air. There were variations in the size of the rooms and in the total volume of fruit in each, but air circulation was approximately the same in each. In one room Rhode Island Greening apples were stored alone. In a second room this variety was stored with mixed lots of apples, the majority of which were McIntosh. A third room in which Greening were stored alone was air-conditioned with brominated

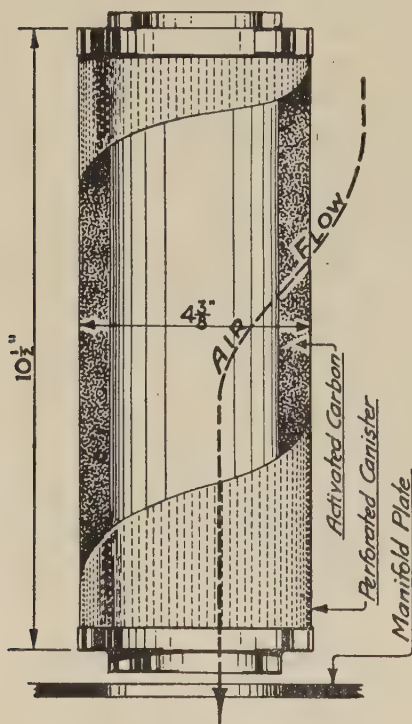


FIGURE 3. DIAGRAM OF A CANISTER OF ACTIVATED CARBON AS USED IN THESE STUDIES

activated charcoal. The activated carbon held about 25 per cent by weight of bromine. The atmosphere was passed through an air-conditioning tower containing four canisters (figure 3) of brominated charcoal and four of unbrominated. These last were used to catch any free bromine that might escape from the first set of canisters. A blower moved air through the unit at the rate of 115 cubic feet per minute. The volume of the room was approximately 600 cubic feet. The brominated charcoal was not replaced during the course of the experiment. Results are given in table 22.

It may be seen in table 22 that, upon removal from storage, there was almost nine times as much scald on Greening when stored with mixed varieties. After four days the difference was not so great but there was three times as much severe scald on the Greening fruits stored with mixed varieties. The Greening that were air conditioned had very little scald upon removal from storage, and that was only barely discernible. After four days at room temperature there was 19 per cent

scald, but practically all of this was slight. These apples could have been sold without a drastic discount in price because of scald.

On the basis of this test, commercial trials of air-conditioning with brominated activated carbon would seem justified on this variety to control scald.

Results are not shown in table 22, but oiled paper was used on some lots of fruit in each of these rooms. On the Greening stored alone there was 22 per cent severe scald where oiled paper was used, after 4 days at room temperature. There was practically no severe scald where Greening fruits were air-conditioned with brominated activated carbon. Hence it would seem in this one test that air-conditioning might give better scald control than would oiled paper.

TABLE 22. SEMICOMMERCIAL TRIAL OF EFFECT OF MIXED VARIETIES ON SCALD OF GREENING AND OF AIR-CONDITIONING TO CONTROL SCALD AT 40° F. (1943-44)

Treatment	Scald upon removal 1/3/44			Scald after 4 days 1/7/44		
	Slight	Severe	Total	Slight	Severe	Total
	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
Greening alone.....	9.09	0	9.09	34.70	36.08	70.78
Greening with mixed varieties.....	39.16	41.82	80.98	8.43	91.16	99.59
Greening air-conditioned.....	1.29	0	1.29	18.56	0.84	19.40

INFLUENCE OF ONE LOT OF APPLES ON ANOTHER IN CONTROLLED-ATMOSPHERE STORAGE

In these experiments two-bushel lots of apples were held in chambers of 55-gallon capacity. Where two varieties were used, one bushel of each variety was included in the chamber. Atmospheres of 5 per cent carbon dioxide and 2 per cent oxygen at 40° F. were used. Unless otherwise specified, the atmospheres were supplied artificially; that is, additions of nitrogen, carbon dioxide, and oxygen were made once daily as required to readjust the atmospheres. This flushing technique is open to some criticism in this type of experiment because scald gases would tend to be removed at least to some extent. Experience has shown that scald tends to be less when this technique is used than when commercial controlled-atmosphere storage is simulated with a closed-system pump and an atmospheric wash of caustic soda. No oiled paper was used.

Duchess of Oldenburg and Northern Spy. These two varieties were stored both alone and together during the 1940-41 season. By the time the Northern Spy was ready for storage the Duchess fruits were fairly ripe, having been held at 40° F. until that time. Results are shown in table 23.

TABLE 23. EFFECT OF DUCHESS ON SCALD OF NORTHERN SPY IN CONTROLLED-ATMOSPHERE STORAGE (1940-41)

Treatment	Total scald after storage	Total spot scald after storage
	3/1/41	
	<i>Per cent</i>	<i>Per cent</i>
Northern Spy alone.....	0.0	None
Northern Spy with Duchess.....	2.6	Severe

Scald differences were small in this experiment, but there was slightly more scald on Northern Spy in the presence of Duchess. There was considerably more spot scald on Northern Spy when stored with Duchess.

Wealthy and McIntosh. In this experiment in 1940-41, prime Wealthy and McIntosh were stored together. Results are given in table 24.

It is apparent from these results that McIntosh induced scald on the Wealthy. Wealthy had no effect on McIntosh.

McIntosh and Northern Spy. In this experiment during 1942-43, McIntosh and Northern Spy were stored both together and separately. Results

TABLE 24. INFLUENCE OF McINTOSH ON SCALD OF WEALTHY IN CONTROLLED-ATMOSPHERE STORAGE (1940-41)

Treatment	Total scald after storage 3/1/41
	Per cent
Wealthy alone.....	0
Wealthy with McIntosh.....	54.0

are not presented, but it was obvious that neither variety affected scald production on the other.

McIntosh and Rome Beauty. McIntosh and Rome Beauty were stored both separately and together during the 1942-43 season. There was 17.2 per cent scald on the Rome Beauty when stored alone and only 1.96 per cent when stored with McIntosh. Why there should be less scald on Rome Beauty stored with McIntosh is not clear.

McIntosh and sun-colored McIntosh. Prime McIntosh and sun-colored McIntosh (postclimacteric) were stored both together and separately during the 1942-43 season. Neither one seemed to affect the amount of scald on the other.

McIntosh and Cortland. In this experiment during 1941-42, McIntosh and Cortland were stored both separately and together. The atmospheres were maintained as in commercial controlled-atmosphere storages; hence there was no flushing with gases, but the atmosphere was washed with alkali solution. The results are given in table 25.

TABLE 25. EFFECT OF McINTOSH ON SCALD OF CORTLAND IN CONTROLLED-ATMOSPHERE STORAGE (1941-42)

Treatment	Scald after storage 3/4/42			Scald after 2 days at room temperature		
	Slight	Severe	Total	Slight	Severe	Total
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
McIntosh						
Alone.....	0	0	0	2.9	0	2.9
With Cortland.....	0	0	0	0	0	0
Cortland						
Alone.....	12.3	80.4	92.7	0	100.0	100.0
With McIntosh.....	60.0	32.7	92.7	0	100.0	100.0

The Cortland had no significant effect on the McIntosh although there seemed slightly more scald on the control. With the Cortland there were no differences in the total amount of scald.

The foregoing experiment was repeated during the 1943-44 season. Sun-colored McIntosh were used. Cortland stored alone or with sun-colored McIntosh all developed about the same amount of severe scald.

REMOVAL OF SCALD GASES IN CONTROLLED-ATMOSPHERE STORAGE

Scald gases are ordinarily absorbed in controlled-atmosphere storage by the use of oiled paper. However, there are certain objections to the use of oiled paper; these are pointed out under *Discussion and Practical Considerations*, page 31. Since the atmosphere is being modified anyway to control certain gases, it seemed desirable to test the possibility of "washing out" scald gases.

Control of McIntosh scald. During the 1942-43 season, various materials were tested as to their ability to control scald on McIntosh with two-bushel lots of fruit. The setup was patterned as nearly as possible after a commercial installation of controlled-atmosphere storage. The atmosphere of 5 per cent carbon dioxide and 2 per cent oxygen was maintained by use of a wash tower of caustic-soda solution and ventilation as required. A total of 80 grams of activated lignite charcoal and of charcoal on which bromine was adsorbed was used. It was found that some bromine was escaping from the brominated charcoal, so a small tube of activated charcoal was placed in front of the former to adsorb the free bromine. A similar tube was placed in front of the plain, activated lignite charcoal. Seventy-five cc. of Oliva 27 oil was used in the manner described in previous experiments; it was repoured over the column of glass beads every other day. The oil and the charcoals were changed once a month until February, and then not again until the middle of April. The alkaline potassium permanganate was used when it was found necessary to add fresh alkali to absorb excesses of carbon dioxide. In other words, the permanganate was merely an adjunct to the regular caustic-soda wash. This meant that about 10 cc. of alkaline permanganate was used in 100 cc. of water about every second or third day. The sodium-hydroxide treatment involved washing with concentrated caustic-soda solution every day. This meant that the atmosphere in this instance was 0 per cent carbon dioxide and 2 per cent oxygen.

In the oiled-paper treatment one-half pound of shredded oiled paper was placed in a mixing chamber in series with the tower of caustic soda through which the atmosphere was circulated continuously. This paper was not changed throughout the experiment. Experience has shown that a similar amount of paper around the fruit would usually control scald on this variety.

From table 26 it can be seen that there was considerable scald on these McIntosh after the June 1 examination. Activated lignite charcoal had a

TABLE 26. REMOVAL OF SCALD GASES FROM MCINTOSH IN CONTROLLED-ATMOSPHERE STORAGE (1942-43)

Treatment	Scald after storage 5/31/43	Scald after 3 days at room temperature		
	Total	Slight	Severe	Total
	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
Control.....	0	26.98	31.74	58.72
Charcoal (lignite).....	0	25.0	17.64	42.64
Brominated charcoal.....	0	0	0	0
Oliva 27 oil.....	0	33.84	16.92	50.76
Alkaline potassium permanganate*.....	0	31.34	19.40	50.74
Sodium hydroxide.....	0	0	0	0
Oiled paper.....	0	30.45	17.54	57.89

*No CO₂.

slight but not significant effect in reducing the scald. The oiled paper (not around the fruit) had no effect on the scald. The oil wash and the alkaline potassium permanganate had only a slight effect in reducing the intensity of the scald. Continuous washing in strong sodium-hydroxide solution seemed to control the scald. It should be noted in this instance, however, that the concentration of carbon dioxide was zero, whereas 5 per cent was used in the other treatments. Passing the storage atmosphere through brominated charcoal seemed to give perfect control of scald; in addition, the apples given this treatment were considerably firmer than the control apples. The effect on ripening has been reported in a separate publication (Smock, 1943).

Semicommercial trials of removal of scald gases in controlled-atmosphere storage. Several trials were made in 300- and 1800-bushel chambers to condition the atmosphere to remove the gas or gases responsible for scald. The trials were made in controlled-atmosphere storage at 40° F., as has been described in another publication (Smock and Van Doren, 1941). No oiled paper was used on the test fruit.

1. The first trial was made with McIntosh and Cortland during the 1940-41 season. Oil was recirculated in an atmospheric washer (Smock and Van Doren, 1941). The oil used was Prorex F oil. This oil had a viscosity of 100 seconds at 100° F. with a 395 "flash", a plus 25 "pour", and a low rate of oxidation, according to the manufacturer's description. Twenty-five gallons of oil was used in the atmospheric washer, and this was changed once during the storage season. The rate of air flow through the washer was approximately 12 cubic feet per minute. The size of the treated chamber was 840 cubic feet. The fruit occupied a large part of the air space, however. Two control chambers were used. One control held 300 bushels and was entirely comparable to the oil-treated chamber, and the other held 1800 bushels. Forty bushels in each 300-bushel chamber comprised Cortland, and the remainder was McIntosh. Only two bushels of Cortland apples were included in the 1800-bushel room, the remainder being McIntosh.

It may be seen in table 27 that scald was controlled by the use of this oil wash for the atmosphere. The inconclusive feature of the experiment

TABLE 27. EFFECT OF OIL-WASHING THE ATMOSPHERE TO CONTROL SCALD ON MCINTOSH AND CORTLAND IN CONTROLLED-ATMOSPHERE STORAGE (1940-41)

Treatment	Capacity of chamber	Scald after storage 2/25/41			Scald after 3 days at room temperature		
		Slight	Severe	Total	Slight	Severe	Total
	Bushels	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
McIntosh							
Control.....	300	0	0	0	13.0	0	13.0
Control.....	1,800	0	0	0	8.0	2.0	10.0
Oil-washed.....	300	0	0	0	0	0	0
Cortland							
Control.....	300	0	0	0	8.5	25.7	34.2
Control.....	1,800	0	0	0	22.2	16.6	38.8
Oil-washed.....	300	0	0	0	0	0	0

was that it was finished about March 1, whereas many controlled-atmosphere storages are not opened until April or May.

2. An attempt was made here to control the scald on 1800 bushels of McIntosh by air-conditioning the atmosphere with an oil. The atmosphere of a 300-bushel chamber of McIntosh was passed through lignite charcoal. There was no large control chamber in this trial. The control consisted of only 2 bushels of McIntosh held in a closed system similar to that described in previous small-scale experiments.

The large room treated with oil was given an unusually severe test in that 300 bushels of the apples were windfalls. It has been shown in previous experiments that ripened fruits may stimulate scald on prime fruits. Twenty-five gallons of Oliva 27 oil was used in an atmospheric scrubber. This oil was changed on December 28, 1942. The rate of air flow was 12 cubic feet per minute.

The 300-bushel chamber treated with lignite charcoal had about 50 bushels of windfalls included with the prime fruits. Thirty-five pounds of activated lignite charcoal was placed in a 7-inch pipe attached to a blower which was left in the chamber. The charcoal was changed on January 6, 1943. This mass of charcoal slowed down the air flow tremendously. It moved at the rate of only 4 cubic feet per hour through this charcoal; the room was 840 cubic feet in size.

TABLE 28. EFFECT OF OIL-WASHING AND OF LIGNITE CHARCOAL ON SCALD OF MCINTOSH IN CONTROLLED-ATMOSPHERE STORAGE (1942-43)

Treatment	Capacity of chamber	Scald after storage 4/1/43	Scald after 4 days
	<i>Bushels</i>	<i>Per cent</i>	<i>Per cent</i>
Control.....	2	0	13.7
Lignite charcoal.....	300	0	0*
Oil wash.....	1,800	0	4.0

*Prime apples in this room showed no scald, but the immature lots showed 30 per cent scald.

From table 28 it may be seen that there was a slight amount of scald where the atmosphere was oil-washed. It is not clear whether the less favorable results obtained in this experiment than in the first semicommercial trial were due to the presence of the ripe apples or to a different oil. It is considered that control of scald should be better than this. It would seem from table 28 that perfect control was obtained with the lignite charcoal. This was true on the prime apples but on some of the greener lots there was as much as 30 per cent scald. Because of this, it is felt that the experiment with this material was not completely successful. In view of the fact that this type of charcoal was not completely effective in controlling scald in the small-scale experiments, no further trials will be made with this material.

After the Oliva 27 oil had been in use in this 1800-bushel room for three months it was analyzed by Dr. G. W. Pearce of the New York Agricultural Experiment Station at Geneva. He analyzed also a sample of the oil before it was used and another small sample of the same oil through which had been passed the vapors of two bushels of ripe McIntosh stored at room temperature for two weeks. He measured the Saybolt viscosity at 100 F.,

the kinematic viscosity index, the density, the refractive index, the specific refraction, the analine point, and the percentage of aromatic rings, naphthene rings, and paraffin side chains. He found no changes in any of these characteristics. This must mean that the causative agent of scald was in true solution in the oil or was present in such minute quantities that it did not change any of the properties of the oil.

3. During the 1943-44 season an attempt was made to control scald on 1800 bushels of McIntosh in controlled-atmosphere storage by means of atmospheric-conditioning with brominated activated carbon. Five per cent carbon dioxide and five per cent oxygen at a temperature of 40° F. were employed.

Four canisters of brominated activated carbon were used for this room. Each canister (figure 3) contained 1½ pounds of cocoanut-shell carbon. This carbon had been impregnated with 23 per cent by weight of bromine. Hence the four canisters contained about 1½ pounds of bromine altogether. The atmosphere was passed through these four canisters and thence through four canisters of unbrominated activated carbon. This last was found not to be necessary because no free bromine seemed to escape from the brominated carbon.

The capacity of the blower used on this atmospheric-conditioning unit was 154 cubic feet per minute, but because of the resistance to flow created by numerous elbows in the pipes leading into the room, the flow into the room was only 12 cubic feet per minute. This rate of movement resulted in a complete change of the atmosphere once in seven hours. It is thought that this was not often enough in the light of the results obtained.

Epimasty tests showed that the brominated carbon had lost its power to remove ethylene after three months. The canisters were not replaced during the entire test. In future tests eight canisters of brominated carbon will be used in rooms of this size.

Since there was no "control" room in this trial it is difficult to evaluate the results, but the results were very satisfactory from a commercial point of view. A large number of bushels of apples were inspected after they had stood at room temperature for several days after removal from storage about April 1. On the well colored fruits no scald was found. On some of the greener or more immature lots of fruit an average of 1½ per cent of slight scald was found. On two boxes of fruit that were apparently in a spot that had poor atmospheric circulation there was 8 per cent of slight scald. The average amount of scald on all lots of fruit examined was a very small fraction of one per cent.

Similar apples held in ordinary cold storage developed 25 per cent scald when no oiled paper was used. The only comparison that can be made with controlled-atmosphere apples is with some rather immature McIntosh held in 2-bushel chambers. These apples developed 100 per cent scald when no oiled paper was used.

Despite the criticisms apparent in the comparative results of this trial, it is felt that as a commercial venture it was very successful. Its success is even more striking when one considers that the bromine had apparently all been dissipated by January 1, and that movement of the atmosphere was comparatively slow.

The quality of the fruit held in this room was striking. Because of the

complete elimination of foul odors by the activated carbon, fruit quality was higher than in any other test that has been made in this type of storage over a six-year period.

4. An independent trial of atmospheric-conditioning for McIntosh in controlled-atmosphere storage was made by the junior author at Storrs, Connecticut, during the 1943-44 season. His results (to be published in a separate report) show considerable promise in the use of brominated carbon for scald control.

DISCUSSION AND PRACTICAL CONSIDERATIONS

A summary of all the investigational work on scald would seem appropriate so that fruit growers may consider all the practical aspects of scald control. All phases of the problem were not covered in this investigation, and some phases were dealt with on a small scale. Hence, the work of other investigators is summarized, as well as that done in this study.

ORCHARD FACTORS

Orchard fertilization. Work done in this study has not indicated that the use of nitrogen fertilizers increases the amount of scald on Rhode Island Greening and McIntosh. It should be noted, however, that fertilization was not continued on the same trees over a period of years, and that the fertilized trees were not brought to a state of extremely high vigor. High tree vigor may account for the fact that it is commonly thought by growers that nitrogen applications increase scald. Gourley and Hopkins (1931) working in Ohio, found increased scald susceptibility after additions of nitrogen to the soil. Studies in Maryland by Degman and Weinberger (1934) revealed no consistent effect from year to year. Savage (1941), working at Cornell, found scald susceptibility of Cortland to be actually reduced by nitrogen additions.

It would seem safe to conclude that the reasons for using nitrogen far outweigh any reasons for not using it, from the standpoint of scald. This is true especially with a green variety such as Rhode Island Greening. Other factors that affect scald susceptibility would seem far more important than this one. Kidd and West (1938) found increased susceptibility to scald where additions of potassium were made to the soil. Although no special study was made of this point in this investigation, it was observed that Rhode Island Greening apples grown on potassium-deficient soil matured earlier and were yellower than fruits in the same orchard that had been fertilized with potassium. Addition of potassium to this soil merely seemed to make the trees and fruit normal. Certainly one would not refrain from using potassium on a deficient soil because of less scald on fruit from trees with a low potassium level.

Additions of borax to a soil not particularly deficient in boron were found by Batjer and Haller (1942) to reduce scald on trees. They attribute this to an advanced maturity caused by the borax. Borax would not be recommended for reducing scald for this reason, however.

Water supply. Brooks, Cooley, and Fisher (1919a) stated that apples forced late in the season by heavy rains or by irrigation were more susceptible to scald in storage.

Fruit size. It seems generally recognized that large fruits are more susceptible than small. It is possibly for this reason that fruits from young trees are often more susceptible than those from older trees. No study was made of this point in this investigation, but it was observed that small fruits were not necessarily more resistant to scald. Many fruits as small as 2 inches in diameter developed as much as 100 per cent scald.

Orchard culture. Any effect of orchard culture would probably be indirect, through its effect on water and other soil conditions. Plagge and Maney (1924) working in Iowa, report reduced scald from trees in blue-grass sod, as compared with those that had clean cultivation or clover cover crops.

Limb treatments. None of the limb treatments that were given in this investigation seemed to throw much light on the real nature of this disorder. Neither did they encourage any practical attempt to alleviate the trouble by limb-shading, fruit-shading, or defoliation.

Limb-shading with cheesecloth often reduced the amount of scald in storage. It is not clear whether this is a direct or an indirect effect. This treatment usually resulted in rather severe shriveling, and badly shriveled fruits usually do not scald so badly as do normal fruits. Hence the results from this treatment do not necessarily imply that no pruning (more shade) would result in less scald.

Defoliation usually resulted in reduced scald, although the reason for this is not clear. Certainly it has no practical implications.

Shading individual fruits with white paper seemed to increase scald. The reason for this was not determined.

Miscellaneous orchard factors. Dustman and Duncan (1940) reported less scald on apples sprayed with thiocyanate compounds. Trials with these sprays at Cornell did not show any promise. There was considerable leaf injury and advanced fruit maturity. Any effect on scald probably results from this effect on maturity.

Brooks, Cooley, and Fisher (1919a) reported that apples affected with cedar rust had less scald than did those that were normal.

PRESTORAGE FACTORS

Fruit maturity. Apple growers have known for a long time that fruit picked early was more susceptible to scald than was late-picked fruit. This study has emphasized the effect of time of harvest on susceptibility to scald. Even the latest-picked Rhode Island Greenings will develop scald in some years, however. Late picking does not seem to be an answer to the scald problem with Greening, since this variety is sold as a green cooking apple. With Cortland, delayed picking may be of some advantage from this standpoint, since the quality of this variety is best when ground color is well developed. However, if allowed to hang on the tree too long, it develops breakdown in storage.

Delayed storage. The results obtained by various investigators on this point are conflicting. Brooks, Cooley, and Fisher (1919b) have pointed out that the degree of air movement in the stack of fruit during the period of delay determines the success of delayed storage. This may account for the conflicting results of various investigators.

This point was not studied in detail in this investigation. It was observed, however, that a delay of 7 to 14 days would often reduce susceptibility to scald. This is probably related to the maturity factor. It would seem just as wise to let the fruit ripen on the tree as on a warm packing-house floor if there were any advanced maturity from this standpoint. The delayed-storage Greenings softened considerably and wilted slightly during the period of delay on the packing-house floor. If the fruit is held at a high temperature and a high relative humidity during the period of delay, the wilting factor would not be serious, but this is hardly practical.

Hitz and Haut (1941) have suggested delayed storage followed by waxing to reduce scald on Grimes Golden. The waxing checks further loss of moisture of these apples in storage and a fair degree of scald control is obtained.

Fruit coatings. This study has shown that waxing the Rhode Island Greening variety with a wax designated as 489 AM (6-8 per cent solids) would significantly reduce scald. Other waxes tested did not have this scald-reducing effect. In the later pickings, its use was just as effective in reducing scald as was oiled paper. It had the advantage over the oiled paper in that it left the fruit in a more attractive condition, and reduced loss of moisture from the fruit during storage. The cost of waxing should be slightly less per bushel than that of one-half pound of shredded oiled paper. It is recommended that small-scale commercial trials of this material be made. Work by Van Doren (1944) in New York has shown the commercial possibility of this wax.

Coating the fruit after harvest with a commercial grade of mineral oil has given inconsistent results in this study. In some years, it gave no scald control but in other years it gave a very significant reduction in scald. In view of the fact that this material leaves the fruit rather oily and messy looking and has not always given scald control, its use is not recommended at present.

Oiled paper. The use of oiled paper either as a fruit wrap or as shreds distributed throughout the package has been considered the standard means of scald control ever since the classic work of Brooks, Cooley, and Fisher (1923). Paper impregnated with 15 per cent by weight of tasteless, odorless mineral oil is used.

This treatment has never received widespread usage in New York State, although small quantities of paper are sometimes used to make the package more attractive. Very few growers use the recommended one-half pound of shredded oiled paper per bushel.

The reasons for this lack of widespread adoption in New York seem to be as follows: 1. The cost factor is sometimes offered as an objection. The recommended amount of shredded oiled paper costs about five or six cents per bushel. This cost would not seem excessive if perfect control of scald were obtained. There is the labor of putting the paper into the package, and another labor charge if the paper is removed before the fruit is sold. These costs are not high, but the labor required does discourage the use of the material. One controlled-atmosphere-storage operator in New York pays one cent per bushel for placing the paper in the package. 2. Buyers sometimes object to quantities of paper in the package. Where oiled paper has been used in controlled-atmosphere storages in New York, it has

usually but not always been removed from the package before sale. 3. The paper absorbs not only scald gases but other gases in the room. If there is a musty odor or a strong wood odor in the room the paper absorbs much of this odor. Unless the paper is removed from the package before sale, it is a source of off flavor to apples in some instances. It has been observed that paper used in controlled-atmosphere storage had these foul odors as long as six months after use. 4. Use of oiled paper is not always a perfect scald-control measure. In years of severe scald it does not always control the trouble on varieties such as Rhode Island Greening. It has always been satisfactory from this standpoint on McIntosh in controlled-atmosphere storage, however. 5. If the paper is very dry when put in the package it may have a drying effect on the atmosphere until it reaches equilibrium with the vapor pressure of the storage atmosphere.

This study would indicate that shredded oiled paper should be re-evaluated as a scald-control measure. Other means of control may in the future prove as effective or even more effective without many of the disadvantages of this material.

STORAGE FACTORS

Temperature. No study was made of this point in this investigation. Brooks, Cooley, and Fisher (1919b) found that scald increased in intensity up to 66° F. Above this temperature it decreased, and no scald could be produced at 77° F. In preliminary work done in this investigation it was found that no scald could be produced on Greening held at room temperature after harvest.

It has been noted in the course of this investigation just from casual observations that scald was worse at higher storage temperatures than at lower. Comparisons were usually made at 32° F. and at 40° F. Eaves and Hill (1940) found more scald on McIntosh at 32° than at 40°.

Brooks, Cooley, and Fisher (1919b) and Kidd and West (1935) found that fluctuating temperatures in storage resulted in reduced scald. The latter investigators raised the storage temperature from 34° to 64° F. for from 7 to 24 hours every two to four weeks. No practical method of control seems to be offered from this observation, however.

Ventilation and circulation. The work of Brooks, Cooley, and Fisher (1919a) clearly indicated that scald seemed to be caused by accumulations of certain gases evolved by the apples themselves. Their work showed a reduction in scald as a result of ventilation with fresh air. Ventilation would hardly seem to be a practical solution to the scald problem. The critical period during scald development is probably during the first month or two of storage, according to the work of Kidd and West (1935); at this time of year (September and October) outside temperatures are often high. The cost of refrigerating enough outside air during these months to ventilate the storage more or less continuously would be prohibitive.

Mere circulation of the storage-room atmosphere does not necessarily reduce the amount of storage scald. Comin (1942) found just as much scald in a room equipped with a blower cooler as in one with coils with no artificial circulation. The authors have observed as much as 100 per cent scald on Rhode Island Greening apples right in the blast of air coming from a blower cooler. This means that the storage atmosphere probably had a

relatively high concentration of scald gases and the fans were merely circulating these gases around the room. In some situations circulation might delay the appearance of scald, but it certainly has no appreciable effect on the final amount of scald.

Carbon dioxide and oxygen levels. Brooks, Cooley, and Fisher (1919a) reported no effect on scald from use of different oxygen levels. They found delayed appearance of scald in the presence of carbon dioxide in the storage atmosphere. Allen (1942) has corroborated this finding.

An attempt was made to study these factors in this investigation but the results are not included because they are not considered reliable, owing to the techniques used. In one experimental setup, the carbon dioxide level was maintained by daily flushing with nitrogen. It follows then that the higher carbon dioxide levels would get less flushing than the lower; hence there would be more flushing away of scald gases with low carbon dioxide levels. In another experimental setup the carbon dioxide level was maintained by varying amounts of atmospheric washing with concentrated sodium hydroxide solution. In a setup such as this there would be more removal of scald gases by the alkali because continuous washing would occur with an atmosphere of 0 per cent carbon dioxide and 2 per cent oxygen. In one experiment there was no scald with 0 per cent carbon dioxide and some scald at 5 per cent carbon dioxide, but this could be attributed to the removal of the scald gases by the alkali. The technique used by Allen (1942) is not subject to these criticisms in connection with carbon dioxide levels, and hence his observations should be given credence.

Scald is likely to be worse on any variety in controlled-atmosphere storage (unless precautions are taken) than in cold storage. This effect is probably due to accumulations of the gas or gases responsible for scald, and not to any specific effect of the carbon dioxide or the oxygen level. The induction period may be delayed or lengthened in controlled-atmosphere storage, but no study has yet been made of this point.

Relative humidity. No critical studies have been made of this storage condition as it affects scald. When humidity regulators are used in laboratory experiments it is difficult not to affect other storage constituents such as scald gases themselves. The work of Brooks, Cooley, and Fisher (1919a) seemed to show that scald was worse in saturated atmospheres. It was the general observation of the authors of this study that scald seemed to be worse when there was free water condensed in the storage chambers, but no special study was made of this point.

Whatever the effect of relative humidity, it would not seem practical to try to control the trouble by manipulating the humidity. High humidities must of necessity be used in storage to minimize weight losses.

Ozone. Several investigators have tested the use of ozone as a possible control of scald. Brooks, Cooley, and Fisher (1919b) and Baker (1933) found no benefit from the use of ozone in the storage atmosphere but they used very low concentrations of ozone. In another report (Smock and Van Doren, 1939) it was found that when a relatively high concentration of ozone was used continuously there was a significant reduction in scald on Rhode Island Greening. This rather extreme treatment seemed to make the natural wax on the fruit very sticky. At least one storage operator in New York claims reduced scald when he used ozone.

It would seem safe to conclude that the use of ozone (when used to control molds in storage) certainly does not increase scald and in some situations may give some reduction in scald when used in sufficient amount. It would not seem to be a practical solution to the problem, however.

The effect of one lot of fruit on another. It has been demonstrated in this study that the vapors of McIntosh may increase the scald on Rhode Island Greening or Cortland. This was shown in small-scale experiments, as well as in semicommercial trials with 300-bushel-capacity rooms. Ripe Rhode Island Greening seemed to increase the scald on Greening picked at the proper time, although the effect was not so striking as with McIntosh. This does not mean that Greening or Cortland will not scald if stored alone. It merely means that storage with McIntosh will sometimes double the intensity of the scald of Greening stored with them.

Just how profitable it would be to store varieties such as Greening separately has not been demonstrated. The desirability of such a practice has not heretofore been considered in cold-storage procedure and may justify some commercial trials.

In addition to this scald effect of one lot of fruit on another there is the ripening effect that a riper lot of fruit may have on a less ripe lot. This effect has been described in another report (Smock, 1943). The scald effect is even more striking than the ripening effect, however.

Air-conditioning to control scald. In a sense, the use of oiled papers is a method of air-conditioning, since the papers remove scald vapors from the atmosphere. Experiments in this investigation show some promise in removing scald vapors by washing the atmosphere.

In experiments in ordinary storage the most promising air-conditioning agent was activated carbon to which had been added bromine. In small-scale experiments where the vapors of McIntosh were passed over Greening, it was found that this agent would completely remove the scalding effect of the McIntosh. In a one-year, semicommercial trial, air-conditioning with this agent gave promising results. It controlled scald better than did oiled paper, when Greening apples were stored alone. Further experimentation is needed with this type of air-conditioning with mixed varieties in the same room.

In trials in controlled-atmosphere storage with McIntosh, various air-conditioning agents were used. Some oils showed promise, but none of them seemed so good as oiled paper. Washing the atmosphere with brominated activated carbon gave good control in a one-year trial.

If further experimental trials show similar results with this air-conditioning agent, its use will be recommended for controlled-atmosphere storage instead of oiled paper. It has several advantages over oiled paper (assuming equal scald control). Its use is somewhat cheaper. It is estimated that its use costs about 3.0 cents per bushel per season, whereas oiled paper costs between 5 and 6 cents per bushel. Another advantage is that use of the activated carbon removes all foul vapors from the storage atmosphere. Fruit removed from controlled-atmosphere storage must ordinarily be "aired out" for several days after opening the storage chamber. Musty odors accumulate throughout the season and these odors are absorbed by the fruit. In a trial with 2000 bushels of McIntosh during the 1943-44 season, it was found that the fruit could be sold immediately after opening

the chamber. Fruit quality in this room was the highest that has ever been obtained in a six-year study at Cornell with controlled-atmosphere storage. Still another advantage has been reported upon previously (Smock, 1943). Washing the atmosphere with brominated activated carbon tends to remove the ethylene evolved by riper lots of fruit. Whether there is any relation between this ethylene removal and the scald control obtained with brominated activated carbon is not known.

Further study is needed on the applicability of this procedure. It is suggested that trials be made with canisters of activated carbon (1½ pounds of carbon per canister) to which has been added bromine at the rate of about 23-25 per cent by weight. One such canister for each 250 bushels of fruit should be used. Each canister should be supplied with an air flow of about 15-25 cubic feet per minute. Further trials may modify these suggested recommendations, but they should supply a basis for future experimentation.

SUMMARY

1. Shading limbs of Rhode Island Greening and McIntosh trees with cheesecloth during the growing season usually, but not always, reduced the amount of scald in storage.

2. Shading individual fruits of these two varieties with white paper seemed to increase scald.

3. Defoliation early in the growing season seemed to result in reduced scald in many instances.

4. Applications of nitrogen fertilizer did not significantly affect the scald of Rhode Island Greening under the conditions of this study. Had a higher state of tree vigor been produced, this result might not have prevailed.

5. A study of the production of total volatile materials and incidence of scald during a three-year period showed a good correlation. That is, when volatile production of McIntosh apples was relatively high, scald severity seemed to be greater. More study is needed on this point.

6. Immature Cortland and Rhode Island Greening fruits scald worse than do those picked later. A practical solution to the scald problem does not seem to lie in this observation, however.

7. Of the fruit treatments prior to storage, the use of oiled paper gave the most consistent reduction in scald. It does not necessarily control scald. Disadvantages in the use of this material are pointed out.

8. One wax emulsion that was tested gave promising results in the reduction in scald. On the later-picked fruit it gave as good scald control as did oiled paper. Use of such a wax has some advantages over the use of oiled paper. Limited commercial trials with this material are recommended.

9. Coating the fruit with a commercial grade of mineral oil gave inconsistent results. In some years it was of no value in reducing scald.

10. Delayed storage of Rhode Island Greening may result in reduced scald, but it does not seem to be an answer to the scald problem because of secondary effects. Delayed storage fruits are likely to be slightly shriveled and to have more bitter pit.

11. A critical study was not made on the effect on scald of relative humidity in storage. Observation revealed that scald was worse when there was free water in the experimental chambers. On the other hand, badly

shriveled fruits usually do not scald badly. This latter may be an indirect effect, however.

12. The vapors of McIntosh apples seemed to increase the amount and severity of scald on Cortland and Greening apples. The vapors of ripe Greening fruits had some effect on less mature fruits in storage, but the effect was not so striking as with McIntosh. This does not mean, however, that these varieties will not scald when stored alone.

13. A number of air-conditioning agents were tested as to their ability to remove scald gases in storage. The most promising one was activated carbon to which had been added bromine. Limited trials on a commercial scale seem to be justified to test the value of this air-conditioning treatment.

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